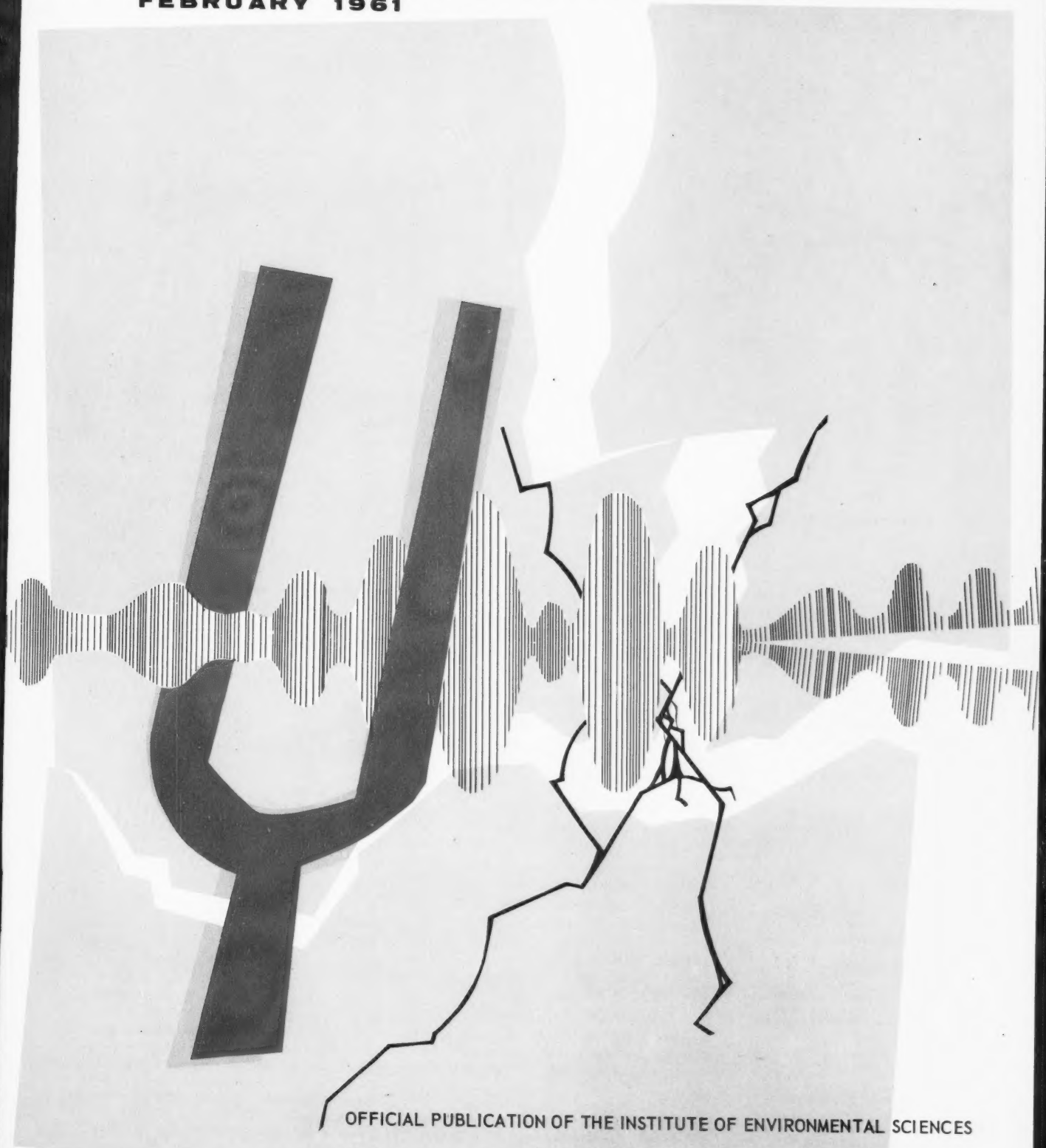
the JOURNAL of environmental sciences
FEBRUARY 1961



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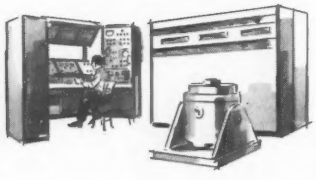

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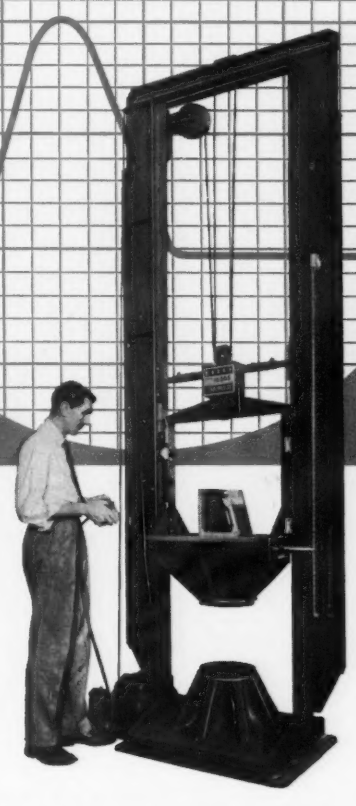

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VOLUME 4 NUMBER 1

the JOURNAL of environmental sciences

For active Environmental Engineers and the executives throughout industry who are concerned with the advancement of Environmental Engineering by the Institute of Environmental Sciences.

Charles W. Le[illegible]on, Technical Editor
Robert Whiting, Assistant Technical Editor

FEBRUARY 1961

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EQUIPMENT TESTING TO SONIC ENVIRONMENTS

by J.A.HILL
NORTH AMERICAN AVIATION, INC.

ABSTRACT

A general description, along with design details, for the equipment qualification sonic testing facility at North American Aviation, Inc., Columbus, Ohio, is presented. Methods of sound generation, control and monitoring and testing techniques are described.

INTRODUCTION

Dynamic motion capable of inducing failures or malfunctions of equipment may be transmitted to a test specimen in one of two ways; (1) vibration through attachments, or (2) acoustic energy transmitted by the surrounding medium. The vibration problem has been rather well treated by many persons, and is generally much better known and understood than are problems created by high energy acoustical noises. The introduction of vibration to structure by means of high level acoustic energy is a relatively young science. It is the purpose of this Article to present the North American Aviation, Columbus Division, method of testing to an acoustic specification to determine the reliability of component parts.

DISCUSSION

Equipment testing at North American Aviation, Inc., Columbus Division, to a sonic environment has been in progress for approximately three months. The facilities were completed in July of this year and calibrated during the month of August. Our first test article was subjected to an acoustic environment in early September. With the exception of a few minor problems, the facilities have performed essentially as designed. In Figure (1) is sketched a general arrangement of these equipment testing facilities. The facility is divided into three areas: an amplifier room, a control room, and a test room.

GENERAL ARRANGEMENT

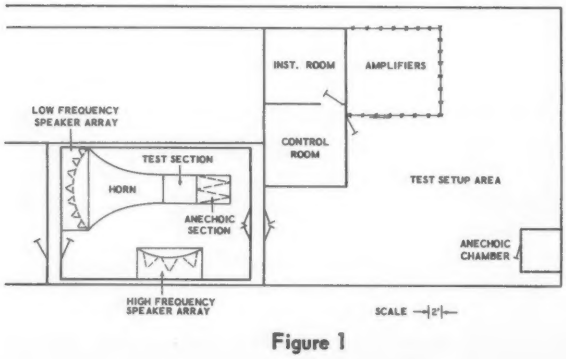


Figure 1

TYPICAL SOUND PRESSURE LEVEL SPECTRUM

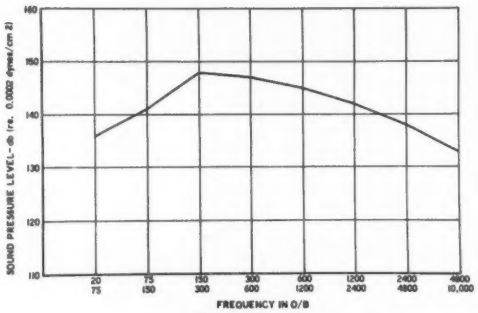


Figure 2

The general purpose of this test facility is to test electronic components, better known as "black boxes". The facility can also be used to test mechanical components such as small heat exchangers, control panels, etc. Some miscellaneous tests in the bio-acoustics area have also been performed in this facility, using it as a very quiet room. It has been found, that on the third shift there is an acceptable noise level for quiet studies. However, since the primary intent for the room was not to be quiet but rather to reduce the outside noise from sound generated within the room, it is , in its present form not the ideal facility for quiet studies. However, with the addition of an available small anechoic chamber inside of this double room, it would be possible to adequately perform quiet studies.

In the design of these test facilities, there were several major items considered: 1) What would be the required test spectrum both in time and sound pressure level? 2) How large must the test chamber be and how will the test article be held in place? 3) What type of sound generating devices should be used to generate the required sound levels over the test section area? In Figure (2) will be seen a typical test spectrum for electronic components in a typical flight vehicle. The test levels seen are for equipment mounted within some type of body or fuselage where it would be expected that the noise levels would be generally less than those impinging upon outer panels. The time required to test to this spectrum typically might be between four and eight hours. In sizing this test chamber it was determined that approximately a three foot by three foot cross section, five feet long would accept the majority of the of the test articles. Mounting is accomplished in one of

two ways: 1) very soft mounting on bungee cords with the test article suspended as seen in Figure (3), or 2) mounted semi-rigidly to the floor of the test section. Mounting impedances which generally play an important part in good environmental dynamic tests and which should be matched with the prototype article, have been simplified to allow laboratory control of end conditions. Soft mounting of the test article is the preferred mounting method due to the wide band frequency of excitation and the inability to avoid resonances in a semi-rigid test mount.

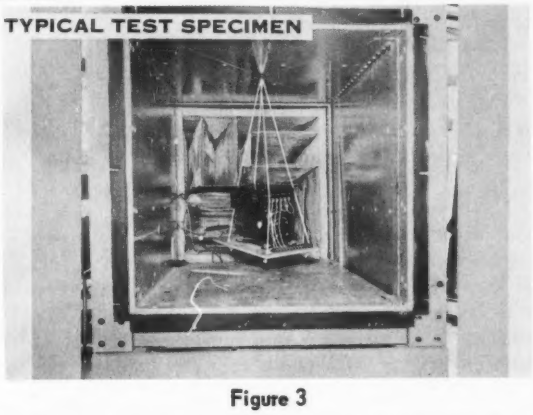


Figure 3

EQUIPMENT TESTING TO SONIC ENVIRONMENTS, FACILITIES AND TECHNIQUES

A search of available sound generating devices to generate a test spectrum with sound pressure levels up to approximately 145 decibels overall with a spectrum shaped high in the mid frequencies and tapering downward at the low and high frequency ends, showed that two different types of speakers should be used; a high frequency speaker with frequency capabilities of approximately 600 cps to 10 kc, and a low frequency speaker with a frequency range from approximately 30 cps to 600 cps. The high frequency speaker selected was the University horn with twelve drivers each, each driver being rated at 50 watts for a total of 300 watts per horn. The low frequency drivers selected were Goodman Audiom 90 speakers, each rated at 50 watts. The high frequency horns have been separated from the low frequency horns

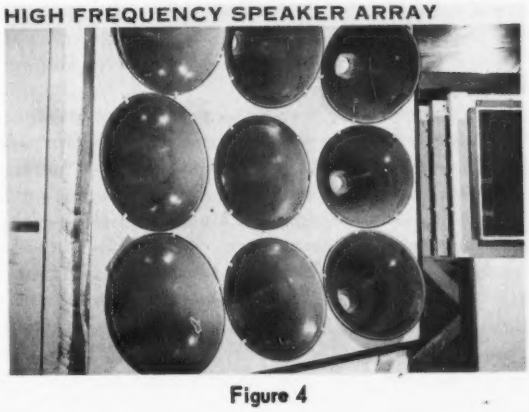


Figure 4

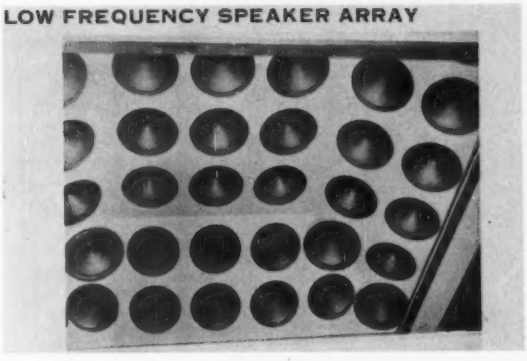


Figure 5

in two different arrays. Figure (4) shows nine high frequency horns mounted in one array and Figure (5) shows forty-nine low frequency horns mounted in the other array. Each of these horn arrays can be coupled through a catenoidal horn (Figure 6) to the test chamber.

A catenoidal horn was selected to couple the speakers to the test chamber because of the better low frequency characteristics as can be seen in Figure 7 (1). It will be noted in Figure (7) that at the low end, near the cutoff frequency, the transmission coefficient is much better for the catenoidal horn than for either the conical or exponential horns, while at the higher frequencies, the horns are nearly identical in their transmission coefficients.

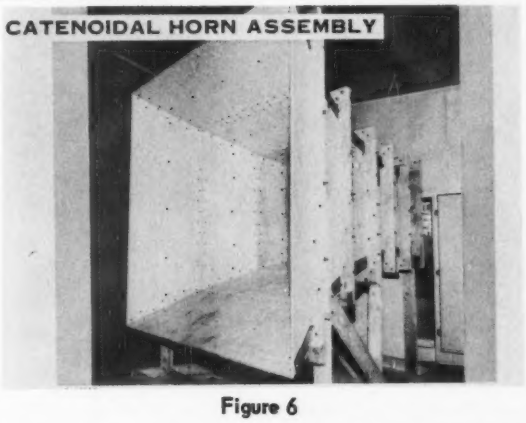


Figure 6

At this point we should like to state that it is suspected that there are some limitations in horn theory when attempts are made to apply this theory to very large horns. The catenoidal horn measures three feet by three feet at the smaller end and approximately eleven feet square at the large end. The horn is about ten feet long. The sound as generated by the horn arrays traveling through the catenoidal horn converges into the test section. The noise is transmitted through the test section in a series of plane waves. The plane waves impinge upon the anechoic section (Figure 11) which represents a suitable termination impedance which reduces reverberation back through the test section. The wedges have a 30 cps cutoff frequency. In Figure (8) will be seen

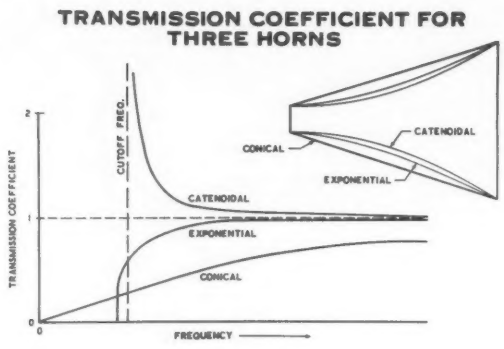


Figure 7

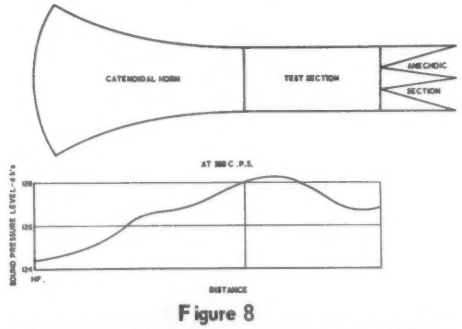


Figure 8

Figure 9

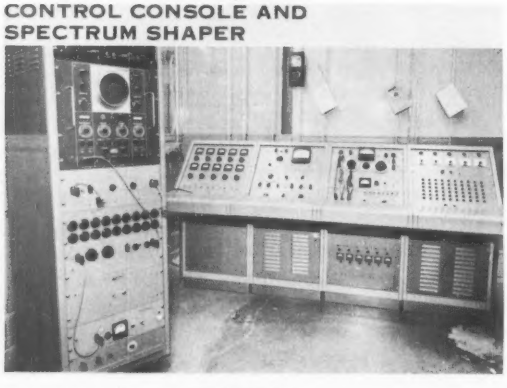


Figure 10

the sound pressure level as measured from the center horn face to the back side of the test section. This was accomplished by moving a microphone along a wire through the center of the horn and test section. It will be noted that this measurement was made at a discrete frequency of 300 cps and that it shows that there was an increase in sound pressure level in the test section over the sound pressure level at any single horn face. This increase in SPL was expected over the entire frequency range. However, due to damping, finite amplitude losses and wave cancellation from reverberant characteristics of the large horn, the gain in SPL does not appear in the higher octave bands.

Each array of horns is powered by nine Savage Mark II, one kilowatt amplifiers. Figure (14) shows the amount of electrical power required to produce about 145 db in sound pressure level over a three foot by three foot test section area. The two curves are based on a four percent and a five percent efficiency in converting electrical power to acoustic energy. Applying a suitable power factor, approximately eight kilowatts of power are required to generate the 145 db. To avoid running at peak power output, a total of nine kilowatts of power are furnished. It will be noted in Figure (9) that the amplifiers are installed within a wire cage for personnel protection. Power from these amplifiers comes into the control room to the left of Figure (9), and in Figure (10) can be seen the spectrum shaper in the left side of the picture and the control console in the center right.

On the left side of the console are meters and impedance matching networks to switch from high frequency to low frequency horn arrays and to individually match power from each of the nine amplifiers. There is a spare meter in this panel. The two center console panels are a system of octave band analyzers, attenuators, and microphone switching units to view by octave bands any of six different microphones placed in the test chamber. The right hand panel in Figure (10) shows five thermocouple meters at the top of the panel which monitor any of five thermocouples placed in or around the test chamber. At the bottom of this panel there are a series of warning lights which glow while a particular speaker or set of speakers are in operation. However, if any of the fused speakers should malfunction, that particular light or series of lights will go out. The spectrum shaper employes a thermal noise source through a series of octave band attenuators to control simultaneously the nine amplifiers. The output of the amplifiers is fed directly to one of the speaker arrays.

Microphones are placed at various points throughout the test section during a test. Usually, one microphone is placed in front of and one microphone is placed behind the test article. Then at the discretion of the test engineer, two or three more microphones will be placed throughout the test section for monitoring purposes. Thermocouples are also placed around the test specimen, in the anechoic section, and around the speakers to monitor temperature rise. There are no provisions for air conditioning in this facility. However, there does exist a compressed air line for supplying cooling air to test articles.

Figure (12) shows the measured sound pressure levels recorded in an empty test section. Sound pressure level variations within the test section traversing from one end to the other vary approximately ± 2 decibels in an empty test section. Traversing from top to bottom or side wall to side wall, as much as ± 3 decibels variation is obtained.

Figure (3) shows a typical test article mounted within the test chamber. This test article will be subjected to a test spectrum similar to the sample of Figure (2). The individual gain controls to each amplifier will be adjusted such that the output of each amplifier to a particular set of speakers is the same. Then with the master gain control the overall sound pressure level with all filters set at zero attenuation will be adjusted to approximately 110 to 120 decibels. The spectrum will then be shaped by adjusting the attenuators which are in one db steps to obtain the desired shape. While each of the attenuators is being adjusted, the overall initial sound pressure level will be maintained with the master gain control.

After the spectrum has been shaped, the test article mounted, and all test article monitoring circuitry connected and checked out, testing will commence. The test operator remains at the console and checks such items as speaker malfunction, sound pressure levels at the various points where microphones are mounted and the temperature rise at the various parts of the test facility. A second test monitor engineer will continuously monitor the various parts of the test article searching for failure or malfunction during the test operation. A typical test monitoring set-up is shown in Figure (13).

It is very desirable to conduct a continuous test over the four to eight hour period, since temperatures and other operating phenonema of the test article can be stabilized. Should a failure or malfunction of some type be indicated by the external monitoring equipment, the test can be stopped and physical checks on the test article easily accomplished. Normally at the conclusion of a test, a physical check both internal and external is performed on the test article to check for failures such as cracked panels. Such failures could have occurred without any indicated malfunction on the monitoring equipment.

CONCLUSIONS

It can be stated that tests are generally conducted in this facility with minimum delay and maximum simplicity.

Some trouble has been encountered with the low frequency horns in that they do not perform to their rated capacity. It has been found that not more than about 20 watts of power can be put into each of the drivers. It is hoped that this situation will be remedied very soon. The vendor of the horns has a new method of coil winding using square wire with a different type of cone material which should allow higher input wattages with better service life for these horns.

Continued on page 25

ANECHOIC TERMINAL SECTION

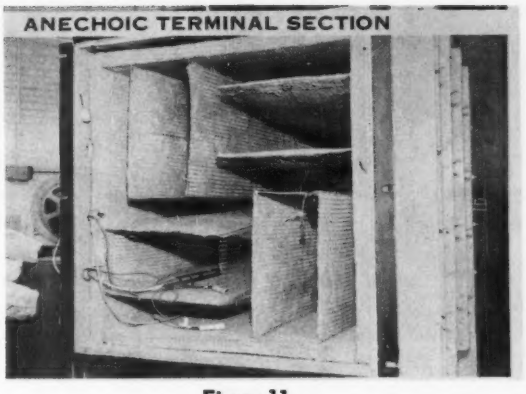


Figure 11

MEASURED SPL IN TEST CHAMBER

LOW FREQUENCY SPEAKER ARRAY		HIGH FREQUENCY SPEAKER ARRAY	
FREQUENCY cps	AVERAGE SOUND PRESSURE LEVEL IN db's (re 0.0002 dynes/cm^2)	FREQUENCY cps	AVERAGE SOUND PRESSURE LEVEL IN db's (re 0.0002 dynes/cm^2)
40	142	250	146
100	141	500	146
220	139	1000	145
500	136	2000	134
		4000	130
		8000	122
37-75	141	300-600	144
75-150	139	600-1200	144
150-300	139	1200-2400	143
300-600	137	2400-4800	131
37-600	134	4800-9600	125
		300-9600	136

Figure 12

TYPICAL TEST MONITORING SETUP

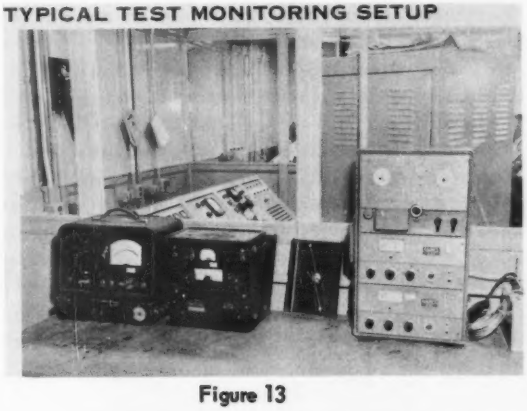
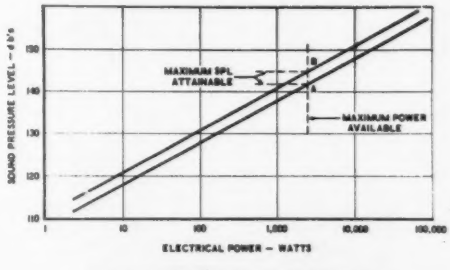


Figure 13



ELECTRICAL POWER REQUIREMENTS FOR DESIRED PRESSURE LEVELS BASED ON THE OVERALL SPEAKER EFFICIENCY OF 5% (A) AND 10% (B)

Figure 14

ENVIRONMENTAL IMAGINEERING

by S.P.SANDERS
BENDIA CORPORATION

ABSTRACT:

One of the most fascinating aspects of an environmental test lab is the constant effort required to develop testing equipment and techniques to meet the military specifications and the demands of the design and development engineers.

This article will describe the solutions of several problems the Bendix Environmental Test Laboratory has worked on during the past two years. Some of the problems are simple and some are not so simple, but they are all interesting. The working engineer would benefit tremendously if more people would document the relatively simple problems and solutions they encounter in their work. The failures should be reported to save wasted time by someone who is using the same approach.

The first example is a simple one. The Environmental Test Lab is required to test the TALOS missile under salt spray (fogproof) and salt water splashproof conditions. The fogproof test requires a low flow, moderate pressure (50 psig) salt water supply and the splashproof test requires a high flow, low pressure (10 feet) salt water supply. The problem was to provide a controlled pressure and flow supply of salt water for a three-minute test. The solution was to order a 400 gal. plastic-lined steel tank.

The sea water equivalent is mixed in the tank and pressurized with shop air through a pressure regulator. The pressure can be regulated to give the specified pressure at the nozzle so the pressure drop in the hose is not a problem. Under large flow-low pressure conditions there is considerable pressure drop in the hose so the pressure is set with the nozzle pointing straight up. The air pressure in the tank is adjusted to give a 10-foot head of water. This eliminates the hose pressure drop completely. Actually, the splashproof test requires a higher air pressure than the fogproof test

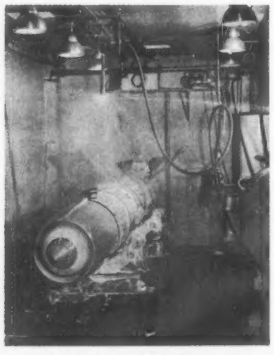


FIGURE 1– A TALOS Missile undergoing a salt water splashproof test

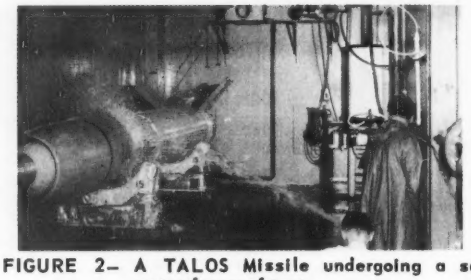


FIGURE 2– A TALOS Missile undergoing a salt water fogproof test

even though the nozzle pressures are 10 feet of water and 40 psig. The 400 gallon tank is large enough to meet the flow rates and the length of test time called for in our specification. The specification calls for sea water or its equivalent. A study of the salinity of sea water revealed that sea water varies from sea to sea, so we settled on a 3% by weight Na Cl solution as a good "sea water equivalent."

Allied to our first example, but also considerably different was a request from the Engineering Department for an environmental chamber to perform cold weather operation and icing tests. The applicable military specification requires that the TALOS missile (weighing over 3000 pounds and 22 feet long) be suddenly immersed in a subzero environment from a normal ambient temperature. The icing portion of the specification requires a fresh water spray test following a sudden immersion in the cold chamber. Of course, the spraying must be done at the subzero temperature.

The E.T.L. altitude-temperature-humidity chamber is big enough to test the missile and the temperature can be reduced to a minus 100 degree F., so the basic equipment was available; but the test technique had to be developed. The first phase was to determine the heat gain, or cold loss, in the chamber when the large door was opened. The main door is 11 feet x 11 feet and exposes the entire end of the chamber. The cold loss was quite rapid with the door open, as you might guess, so a cold barrier curtain was installed. The vinyl canvas curtain covers the entire end of the chamber and has a drop flap similar to the flap in an old fashioned pair of winter underwear. The flap arrangement limited the cold loss to approximately 10 degrees F. per minute of open time. With this system a minus 20 degree F. immersion test is performed with a stabilized chamber temperature of minue 40 degrees F. as it takes about two minutes to move the TALOS missile into the chamber.

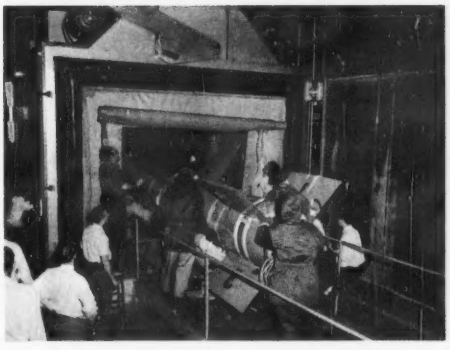


FIGURE 3– Preparing for a cold immersion and icing cold weather operation tests

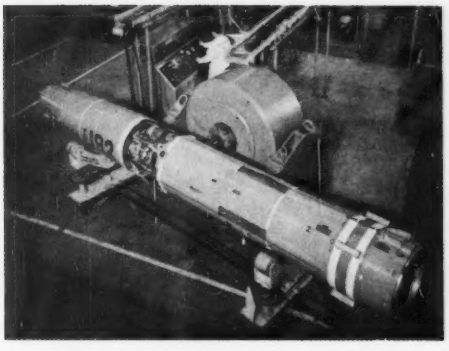


FIGURE 4– Design margin evaluation vibration tests with a 12,500 pound force Electro-dynamic Shaker

on the TALOS missiles.

The large chamber is used for temperature, humidity, and altitude testing. This combination looks good from an economic viewpoint, but it does have its technical drawbacks. The technical drawbacks are minor in a testing activity such as we are engaged in, but they still cause concern. The principal problem is the elimination of water vapor when an altitude test follows a humidity test. The TALOS missile has a ramjet engine and as a result our altitude testing does not compare to the altitude testing of space vehicles. A ten to twenty-thousand-feet difference in the maximum altitude capability of our chamber is important though. We have fought the

This scheme has been very successful for the cold immersion test and the first phase of the icing test. There were several problems in the icing phase of the test. First, what happens to the water in the chamber? A simple solution was to obtain a heavy canvas four feet longer and wider than the chamber floor. The canvas was spread on the floor and the sides folded up and secured to make a container to catch the spray. After the tests the ice is melted and siphoned down the drain. The physical layout of a piping system to perform the icing tests was easy, but there were a few important battle of leakage to the point where we now have a leakage rate of seven cfm of ambient air at altitude conditions. The leakage rate must be viewed in conjunction with the fact that the chamber has two full sized personnel doors, a large door exposing the entire end of the chamber, seven windows, numerous hydraulic and electrical feedthrough connections, and the chamber is built in two sections so a partition can be inserted to make two chambers. We think seven cfm is excellent. With the leakage rate reduced to a minimum the water vapor problem was attacked. Our efforts were directed toward removing the water from the vacuum pump oil. questions which had to be answered. Obviously, the piping must be empty during the chamber cooling period. With the piping and mist nozzles at a subzero temperature would the water freeze and foul the nozzles? We thought it would and set up an experiment to determine the heating cable required to keep the nozzles from freezing. The results of this experiment surprised us. These tests proved there was enough heat in the water to keep the piping from freezing. The exit water temperature was between 35 and 40 degrees F. With this encouragement a spray system was designed and installed in the large chamber. The system consists of the 400 gallon supply tank, a main supply line, two paralled two-inch pipes approximately eight feet apart running parallel to the centerline of the missile and four feet above the missile centerline, and five rain nozzles in each pipe

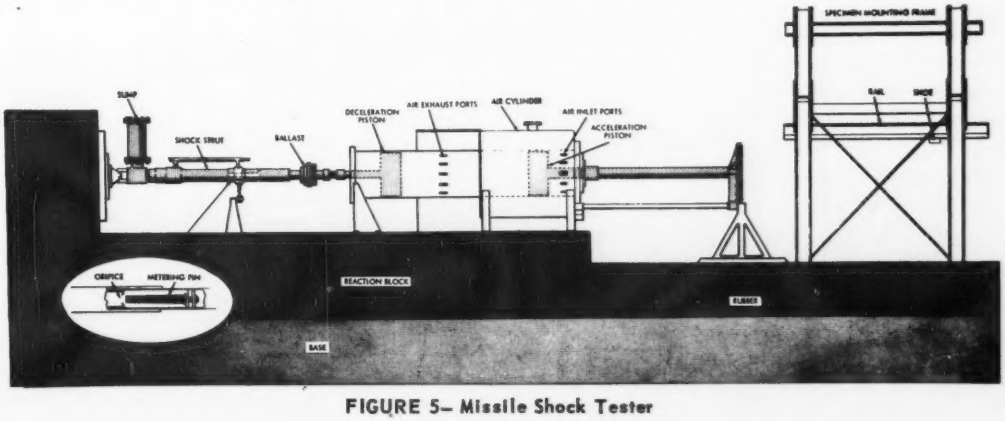


FIGURE 5– Missile Shock Tester

at four-foot intervals. The supply tank is used instead of tap water for two reasons. The pressure can be controlled easily and the water temperature is constant during the test. This is important as icing at the nozzles is directly related to the water supply temperature. We hold this temperature between 50 and 60 degrees F. and the actual water temperature at the nozzle exit is between 32 and 35 degrees F. The system and test technique have worked very well and are used to perform Design Evaluation Tests and Quality Assurance Tests Using gravity separation and dry air stripping techniques, literally quarts of water were removed following a prolonged humidity test. It is a time-consuming process as several days of chamber conditioning time is required to remove all of the moisture, but it is possible to raise the altitude ceiling by about 10,000 feet with this method. The work we did encouraged us to buy a commercial oil purifier which will do a better job of removing water and other contaminants and which will be on the job at all times to keep the altitude equipment in peak operating condition.

It should be obvious by now that this article is basically a series of loosely tied together ideas on day to day problems in environmental testing. While we are talking about chambers I want to describe an experiment we performed on a rapid rate of climb altitude test. Our large altitude chamber has a total volume of 3700 cubic feet and the bell jar has a total volume of 28 cubic feet. Using the large chamber as a vacuum reservoir, a rapid climb rate of 80,000 feet in six seconds has been achieved in the bell jar. A climb rate of 13,000 feet per second is fantastic even in this space age. The problem is to reduce and control the climb rate to the value required for a given missile system. We are studying the problem in our spare time.

I sometimes wonder if environmental engineers realize what a versatile electrical power supply they have in their shaker systems. This was demonstrated several years ago when we had to perform variation in line voltage and variation in line frequency tests on the TALOS Tactical Test Sets. In a flash of genius our vibration expert explained how the rotary power supply for our 12,500 pound shaker system could be used to perform these tests. Since that time we have used the power capabilities of our rotary and electronic powered shaker systems on many occasions. In some cases it may be necessary to use a transformer to get the voltage required. In addition to the voltage and frequency variation capability the systems have a healthy source of D.C. power at either 125 or 250 volts.

Early in the TALOS program (1952, in fact) Bendix designed and built a pneumatic-hydraulic shock tester to simulate the start of the boost phase of the TALOS missile's flight. Two shock testers were built. The first was designed to test specimens up to 250 pounds. The second was designed to test the entire TALOS missile. The details of the missile shock tester are covered in Reference 1, but its basic functions can be described

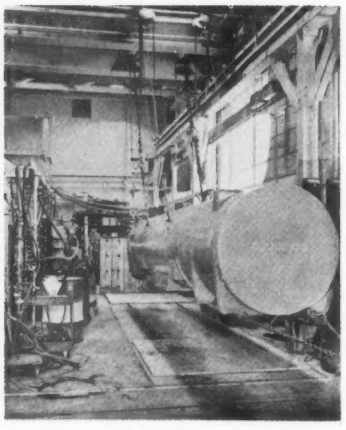
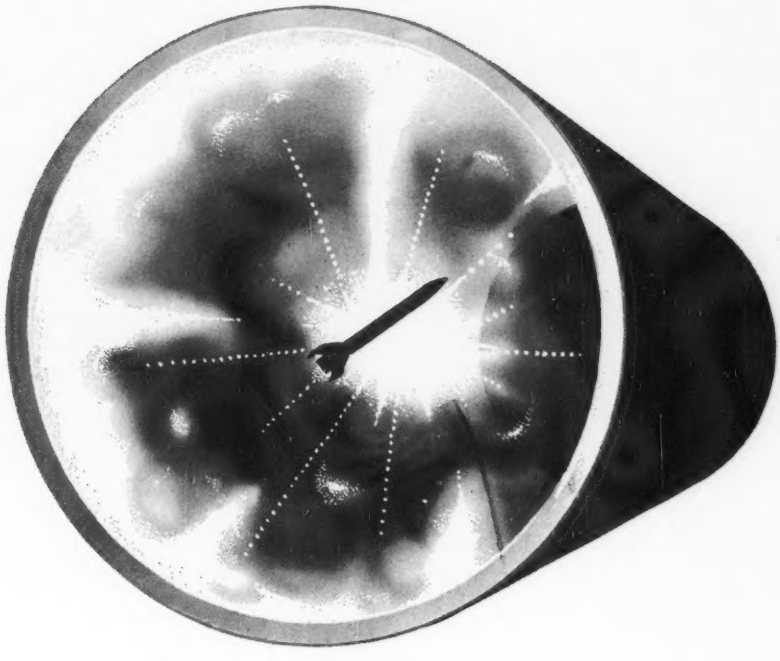


FIGURE 6– Missile and Container ready for a seven-foot free swing into a humping block of structural steel and oak timbers

here. The impact is made in a horizontal plane with a total missile travel of seven feet. The shock tester consists of a 30-inch diameter cylinder with two independently operating pistons. Air pressure at less than 100 psig is used behind one piston to accelerate the missile at approximately five g's for a distance of five feet. During this period the air in front of the piston is free to escape through exhaust ports in the cylinder wall. When the first piston covers these exhaust ports the air column trapped between the two pistons acts as an air spring to couple the moving missile to the energy absorbing hydraulic shock strut. The hydraulic shock strut with its metering pin and orifice decelerate the missile smoothly with a rise time to peak g of about 20 milliseconds and a hold time over 90% of peak g of about 30 milliseconds. The missile is being decelerated backward so the inertia forces which act on the missile are in the proper orientation to simulate the boost phase. Several parameters can be changed to modify the response characteristics -- air pressure, air column length, metering pin profile, metering pin to orifice distance, and mass relationships. The response varies from a trapezoidal shape at 25 g's to almost a triangular pulse at 100 g's. This system has been shock testing the TALOS missiles for the past seven years. Its design and modification has been an interesting part of our mechanical environmental engineers' work.

An interesting test resulted from a request by our Engineering Department to test a G switch. The G switch was designed to be activated as it passed through a zero acceleration condition at a rate of 40 g's per second. We tried two methods. The first utilized our component shock tester with the exhaust ports closed. The system was essentially an air spring with a variable pneumatic source to give the switch an initial acceleration of about 5 g. The hydraulic shock strut helped to prolong the first cycle of the air spring's

Continued on page 23



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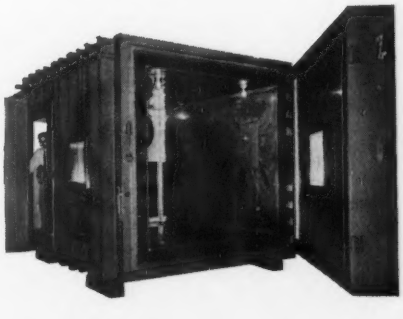

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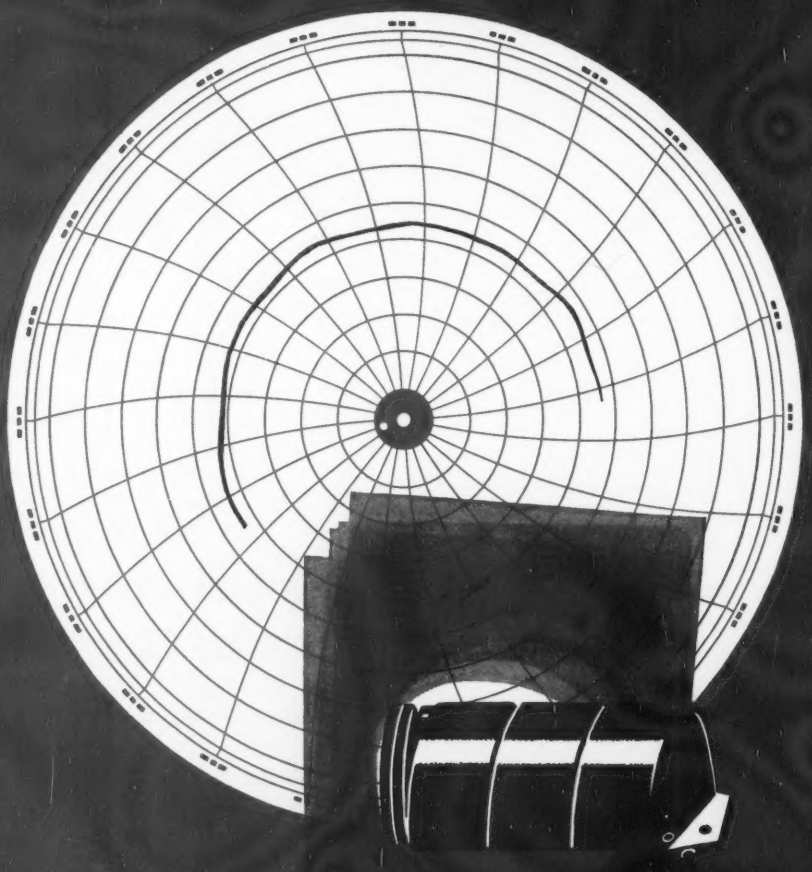

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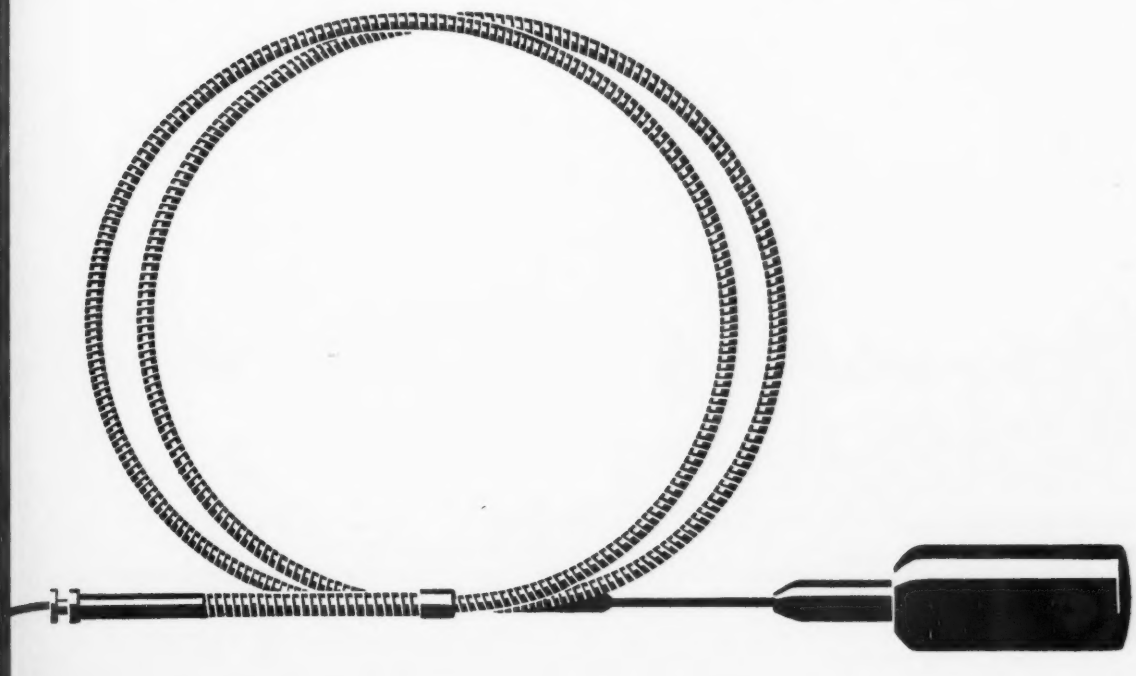

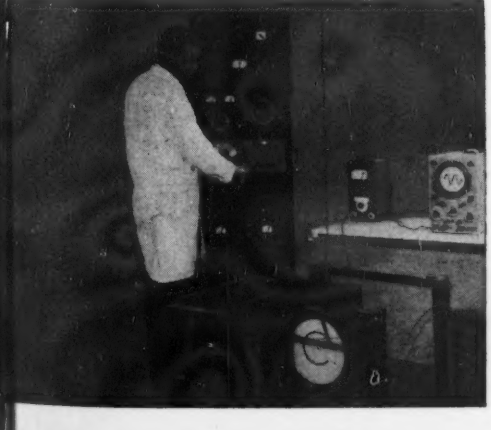

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Gain:	variable 0.5 to 500	variable 0.05 to 3
Gain Accuracy:	better than 3% of reading	not calibrated
Gain Stability:	better than 1%	max. drift 2 mv/°F
Frequency Response:	±10% 10cps to 20KC	±5% 10cps to 10KC
Input Impedance:	75 megohms, min.	25,000 ohms
Noise:	less than 500 u v rms, rti	negligible
Output Voltage:	5 volts rms into 25 K load	±100 ma into 35 to 100 ohm load
Linearity:	better than 2%	better than 2%

INSTRUMENTATION DIVISION

Gulton Industries, Inc. Metuchen, New Jersey

In Canada: Titania Electric Corp. of Canada, Ltd., Gananoque, Ont

MISSILE COMPONENTS ACOUSTIC TESTING

by RICHARD E. LEITHISER
GENERAL ELECTRIC COMPANY

The objectives of component acoustic tests are usually to determine whether the component will perform its function in the acoustic environment predicted at the time the function is to occur, and to ascertain what detrimental effects may have resulted from acoustic environments prior to the prescribed time of function. Specifications vary and are dependent upon the component location within the airframe, the propulsion system and the missile aerodynamic characteristics.

In general, acoustic excitation will randomly vary from 40 cps to 10,000 cps and at sound pressure levels between 135 and 165 db (re 0.002 microbar), with the spectrum peaking between 150 and 300 cps and then falling off at a rate of 3 db per octave.

Random noise is utilized more than pure tones in component testing because the actual environment generated by jet engines and rocket motors is random in nature. However, pure tones are sometimes used for diagnostic investigations of component problems.

Two basic types of test chambers may be employed, the plane wave tube or the reverberant chamber. Plane wave tubes may be used only for small components but develop higher sound pressure levels than reverberant chambers and have an unidirectional field. Reverberant chambers can accommodate larger components and have a diffuse field. Specimens up to one-tenth the volume of the reverberant chamber may be tested without disturbing the diffusion characteristics.

Test items are usually suspended in the chamber with isolating cord in a manner similar to that shown in Figure 1, to eliminate extraneous vibrations. Microphones are placed at different locations around the component to determine the exterior noise level, and a one-third octave band analysis of the type shown in Figure 2, is generally conducted.

A thorough dissertation of the theoretical aspects encountered in evaluating mechanical response to acoustic noise was presented in the October, 1959 edition of the Journal of Environmental Sciences and will not be duplicated here. However, the greatest pitfall in evaluating acoustic response seems to be that of looking for permanent, irreversible, fatigue type failures. These type of failures seldom occur in component testing. The primary concern in component testing should be to determine if the component will successfully perform its function while in the environment in which it must operate. There is no substitute for continuous monitoring; experience has shown that many components will perform satisfactorily following exposure to acoustic noise, but malfunction or distort during exposure. This is demonstrated in Figure 3 which presents the response of a piezoelectric accelerometer to acoustic noise.

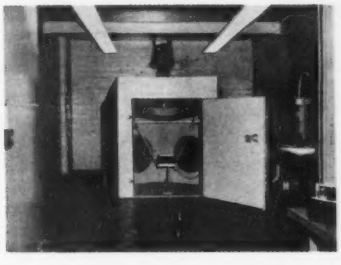

Figure 1 – **The Reverberant–Chamber**

Many times the individual component is not at fault. In one recent instance, replacing a rigid tubing connected to the component with a flexible tubing eliminated the problem. In another case, an electronic tube in the monitoring equipment located outside the reverberant chamber was found to be microphonic although its environment was only 128 db. In both cases, the component would have functioned when removed from the environment, but indicated unsatisfactory performance while in the acoustic field.

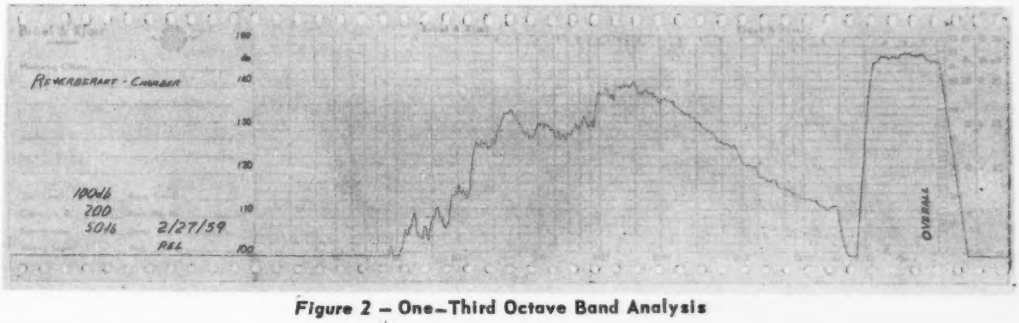

Figure 2 – **One–Third Octave Band Analysis**

Components, tested alone, may perform acceptably in the specified environment, but when connected together as a system fail to meet specification. A good example of this was the rigid tubing problem mentioned earlier. Had the component been tested singly, it would have passed, but when the tubing was connected its performance was undesirable. Problems such as this demonstrate the necessity of system or at least subsystem testing. Small components, particularly those with a high mass density seldom present acoustic problems, but the sonically induced mechanical vibration transmitted through their bracketry or connections may have serious effects on the operation.

Another important consideration is the application of spectrum data rather than over-all levels when establishing test requirements. A ¼ inch thick, 24 in. diameter aluminum disk has an over-all transmission loss of 35 db. From this, one could be lulled into assuming for acoustic prediction purposes that a component shielded by ¼ inch aluminum and which must function when the exterior level is 150 db need only be tested at 115 db. However, at 300 cps, the acoustic attenuation found from Figure 4 is only 28 db, and the component will see in excitation of 122 db, or an acoustic power gain of 5. This is not meant to imply that transmission loss determination should be made from panels or small samples and extrapolated to complete structures. There is no substitute for the complete system.

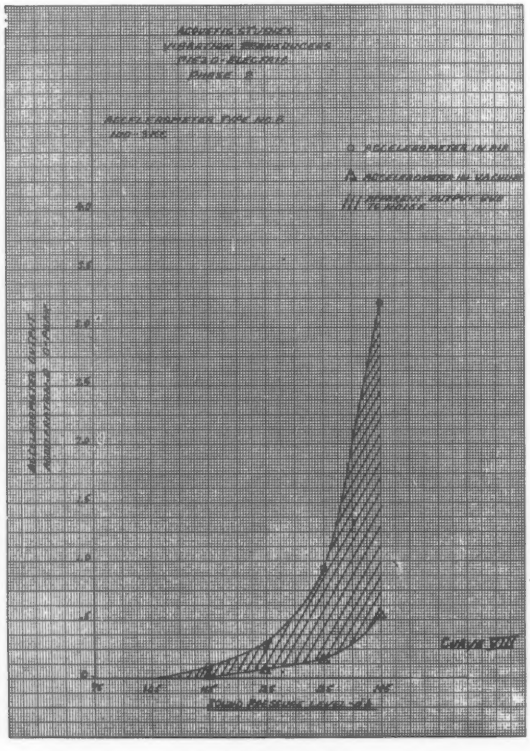

Figure 3 –
Acoustic Response of a Piezoelectric Accelerometer

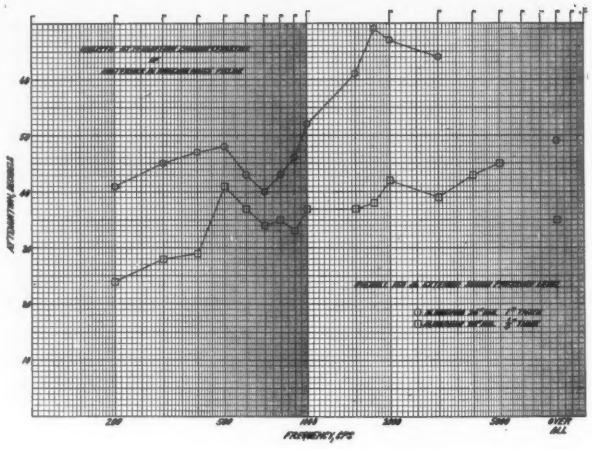

Figure 4

The correlation between mechanically induced vibration and sonically induced vibration is seldom close. Components may have deliberate or accidental vibration isolators between them and the source of mechanical vibration, but airborne noise will circumvent them. Little similarity has been noted in the amplitude response of a component to the two paths of vibration. Items have successfully survived vibration tests and malfunctioned in an acoustic environment, and vice versa. Thus, neither mechanical nor sonic induced vibration can be substituted for the other, and no evaluation program will be complete without both.

Many years of experience have been accumulated in developing the techniques used in mechanical vibration testing and most of these techniques are applicable to the field of sonic testing. These principles should not be ignored simply because a new method of transmission exists. If the vibration experience is transferred to the art of acoustic testing, and if in any evaluation of the acoustic effects on components we determine whether:

1. The component will satisfactorily perform its function in the environment in which it must operate.
2. The environments through which it must pass have effected its capability to operate when required.
3. It will perform as a part of the system.

Then the acoustic environmental test will attain its proper position in the realm of engineering evaluation.

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Preston W. Smith, Jr. and Miguel C. Junger, *"Sound-Induced Vibration"*. Journal of Environmental Sciences, October 1959.

D.M. Shauger, *"Preliminary Acoustic Environment Studies of Acceleration Transducers, Piezoelectric"*, Structures Laboratory Report C59–03, February 1959.

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NOTES FROM THE EDITOR

CHARLES W. DANIELSON
TECHNICAL EDITOR

In previous issues of the Journal, I have discussed briefly some of the environments that were appropriate for articles and have also outlined a format for the preparation of articles for publication. In order to provide a more detailed guide for authors, the following types of environments and environmental criterea are presented. Much of this information was given by William Vandal, President of the I.E.S., in a lecture at the University of California at Los Angeles.

NATURAL ENVIRONMENTS

1. Climatic (Land, Sea and Air)
   a. Temperature
   b. Humidity
   c. Barometric pressure (Altitude)
   d. Wind
   e. Solar Radiation
   f. Dust
   g. Snow
   h. Rain
   i. Frozen water (ice, sleet, hail, glaze, frost)
   j. Atmospheric contaminants
   k. Salt Foq.
   l. Ozone
2. Weather Environments
   a. Temperate climate
   b. Tropical climate
   c. Desert climate
   d. Arctic climate
   e. Polar climate
3. Terrain Environments
   a. Surface Configuration
      1. Mountains
      2. Plains
      3. Rivers and Oceans
4. Biotic Environments
   a. Flora macro vegetation
   b. Micro (fungi, bacteria)
   c. Fauna - animals to insects
5. Other Environments
   a. Electro Potential Phenomenan
   b. Magnetic Phenomenan
   c. Zero Gravity
   d. Metiorites
   e. Radiation

INDUCED (OR MAN-MADE) ENVIRONMENTS.

1. Rough Handling - in manufacture, transit or use
2. Transportation - by land, sea, or air
3. Storage environment - sheltered vs. unsheltered
4. Operation
   a. Shock
   b. Vibration
   c. Atmospheric contamination
   d. Radiation
   e. Noise
   f. Heat generated by componénts and machines
   g. Blast pressures

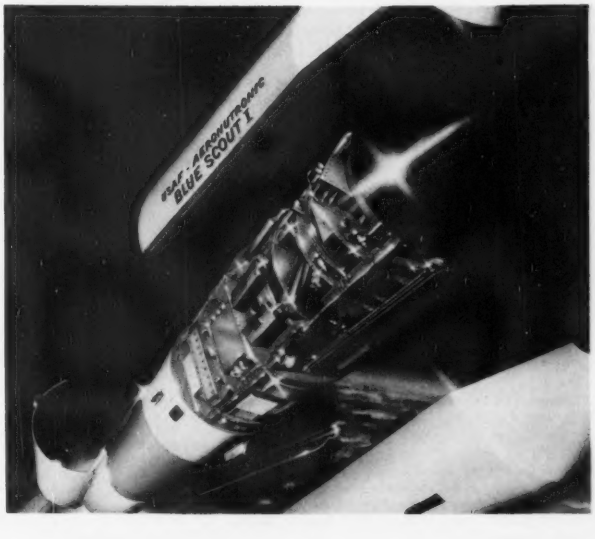
Themes of articles related to the above environments can be in the following categories:

1. Military Specifications and Standards
2. Corrolation of field conditions with laboratory tests
3. Simulating combined environments
4. Laboratory simulation equipment
5. Field test sites
6. Deterioration of equipment as a result of environment
7. Accelerated testing
8. Non-destructive testing
9. Test instrumentation
10. Reliability and Quality Control.

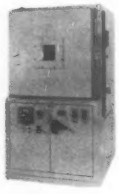
Those persons wishing to submit articles for publication in the Journal may forward rough drafts or finished articles to the attention of the Technical Editor, Journal of Environmental Sciences, 11918 West Washington Boulevard, Los Angeles 66, California (Phone Number – UPton 0-3072).

HIGH ABOVE THE ATLANTIC OCEAN

A U.S. Air Force Blue Scout I three-stage rocket developed by Ford Motor Company's Aeronutronic Division, Newport Beach, Calif., sheds its payload heat shields, exposing Air Force scientific equipment. The solid propellant rocket, launched from the Atlantic Missile Range at Cape Canaveral, Fla., will measure eight different types of environmental conditions in space. The Blue Scout I rocket is the first guided version to be launched in the new Air Force missile-space program. Two previous unguided rockets (Blue Scout Junior) were fired from Cape Canaveral late in 1960. Today's Blue Scout I is slated to reach an apogee (high point) of more than 1000 statute miles. It will impact 1200 miles down range from the Florida missile test site, landing its recovery vehicle by parachute in the Atlantic Ocean near Antigua Island. The Blue Scout rocket program is being carried out under executive direction of the Air Force Ballistic Missile Division of the Air Research and Development Command.



NEW PRODUCTS



200,000' ALTITUDE CHAMBER

New INRECO 20" x 20" x 20" Altitude Chamber designed for testing electronic and hydraulic components.

The chamber has an ultimate altitude of 200,000 feet and a temperature range of −100° F. to 240° F. Pull-down time to −90° F. is 45 minutes and heat-up to 240° F. is 15 minutes. Evacuation time to 150,000 feet is 30 minutes. The chamber has a cold-wall liner for maintaining low temperatures simultaneously with high altitude. A manometer is supplied for indicating altitude.

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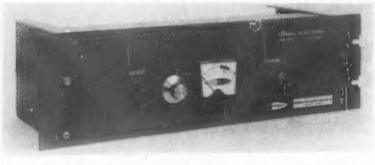

NEW THERMAL NOISE SOURCE GIVES 15 OCTAVE RANDOM NOISE SPECTRUM

A new laboratory instrument that furnishes a random electrical spectrum with a Gaussian amplitude distribution has been developed by Western Electro-Acoustic Laboratory, Inc., 11789 San Vicente Blvd., Los Angeles 49, California.

Designated as the 300C, the product is a laboratory instrument designed for applications such as synthesizing rocket or jet noise spectra, random vibration shake table operation, high intensity noise chamber experiments and reverberation experiments.

The source of noise is derived from thermal agitation within a cold resistor. This source is extremely stable, dependent only upon magnitude of the resistance and the ambient temperature.

New features of the instrument include a low microphonic feedback, an extended frequency range of more than 15 octaves, including subaudible, sonic and ultrasonic and a filter network to allow selection of equal energy per cycle per octave.

The instrument is AC operated, is readily transportable, mounts in standard racks, or can be used in either a horizontal or vertical position or on any convenient surface. All operating controls are mounted on front panel. A panel meter provides a quick check of critical tube currents. Overall size is 19" wide, 5 1/6" high, and 7 3/4" deep.

Technical literature is available and for more details please write the manufacturer direct.

ACOUSTIC FACILITY

Installation and operation of a new acoustic test facility which permits testing of electronic components and sub-assemblies under actual acoustic conditions encountered in jet and rocket propelled missiles and aircraft, at American Laboratories Division, American Electronics, Inc., is announced by W.H. Grumet, Division General Manager.

An overall sound pressure level of 160 db in a test area 1 foot by 1 foot by 3 feet is provided.

Complete monitoring and analysis of actual test conditions is provided by Ling-Altec's model 12185 acoustic calibrator, Model B & K 2141 one-third octave analyser, and complete Ling-Altec Model 21BR180–1 calibrated microphone system. The facility is designed to handle both explosive and non-explosive test samples and can be altered to provide combined vibration, temperature and acoustic environments as required. Contact: American Laboratories Division, American Electronics Inc.,1536 East Ross Avenue, Fullerton, California.

NEW ION PUMP

The availability of a new, large vacuum ion pump for use in the ultra-high vacuum field has been announced by Consolidated Vacuum Corporation, a subsidiary of Consolidated Electrodynamics/Bell & Howell.

The new PDV-300 DriVac pump is an electronic getterion pump utilizing a three-electrode construction which insures high pumping speeds and eliminates pressure surges when operating against inert gases.

The features of the PDV-300 DriVac pump make it especially useful for ultra-high vacuum applications such as semi-conductor processing, vacuum tube processing, electron microscopes, particles accelerators, and field emission, electron beam and molecular beam studies. It has a nominal pumping speed of 300 liter/second with an ultimate pressure of 2×10^{-10} mm Hg--the lowest reading obtainable on a commercial ionization gauge as determined by the X-ray limit of the tube.

NEW PROTECTIVE SUIT FOR EARTH WEAR

A life support system enclosed in an air-conditioned suit that will protect its wearer against completely hostile environments and, with modification, the rigors of outer space, was announced today by The Garrett Corporation's AiResearch Manufacturing Company of Los Angeles.

The system and suit are not limited to missile loading, however, according to Garrett engineers. Other applications include the chemical processing industry in areas of poisonous fumes; fire fighting and rescue; mining; nuclear plants; preflight ventilation of flying suits; or in any area where protection from surrounding atmosphere is needed.

Experience in the development of environmental systems for aircraft and space vehicles, such as Project Mercury and the X–15, enable Garrett's AiResearch Division to produce the protective life support system.

Recently Garrett introduced an application of this system designed for space wear. Called a "Moon Pack," the self-contained, portable system provides breathable air for a man disembarking from a space ship on the Moon or on a space platform.

Weighing only 50 pounds on earth, weightless in space, the newly developed closed circuit oxygen system is carried on the space traveler's back and allows him to set temperature, humidity and ventilation conditions to his liking. It is designed to let the explorer roam the strange environment found outside the atmosphere, overcoming pressures too low to sustain life.

NEW DOUBLE INTEGRATING VIBRATION METER

Provides standardized simultaneous output signals of Displacement, Velocity and Acceleration from any piezoelectric accelerometer. Uses novel sensitivity dial of the Dial-A-Gain Instruments which allows dialing accelerometer sensitivity to give output of one volt per inch displacement and one volt per g acceleration. Displacement or acceleration may also be indicated directly on the internal Meter. Driven shield cable (25 ft. standard supplied) reduces cable capacitance effects to a minimum. Available case mounted or in triple channel units for rack mounting.

Velocity signal is standardized to 96.4 MV (rms)/in./sec. (rms) which is the sensitivity of many velocity type pickups. Adapts to Bruel and Kjaer Shaker Control or other servos to control both displacement and acceleration from any accelerometer; eliminating the need for velocity coils.

Contact: Unholtz-Dickie Corp.
2994 Whitney Avenue
Hamden, Connecticut

MINIATURE ACCELEROMETER

The development of a new miniature accelerometer, the Model 504, having an acceleration range from 0.03 to 40,000 g with a flat frequency response within ±5% from 0.2 cps to 12 kc, has just been announced by Columbia Research Laboratories. A special isolated case design makes the unit particularly suitable for applications where unusual stability and accuracy are required in high noise fields, temperature, altitude, humidity and other severe environments; because of its ideal operating characteristics, it may also be used as a high frequency laboratory standard.

Sensitivity of the Model 504 is 20/mv/g with an amplitude linearity of ±1%. Resonant frequency is 85 kc and temperature range is from -65 degrees F to +350 degrees F for standard units and from -65 degrees to +500 degrees F for high temperature units, with less than ±10% variation in sensitivity throughout both temperature ranges.

For further information on the Model 504 Accelerometer, Columbia Research Laboratories, MacDade Blvd. & Bullens Lane, Woodlyne, Pa.

TECHNICAL INFORMATION

In place of our usual listing of papers presented at the 1960 Annual Meeting, we are donating this space to a preview of the 1961 Annual Meeting and to present a few of the many Topics which will be presented. This year's meeting will be held at the SHERATON PARK HOTEL, Washington 8, D.C. on April 5, 6, & 7, 1961. This years Theme will be: *"Global And Space Environments A Challange to Industry"*. Following is an abbreviated list of papers to be presented:

"Trends in Electronic Equipment Thermal Design and Packaging", By W.E. Krauss, The Martin Company. **"Thermal Control of an Orbital Vehicle"**, By F.J. Sackleh or A. Gross Wright Air Development Division. **"Experimental Equipment & Methodology for Optimizing the Thermal Environment in Manned Hypersonic Aircraft"**, By H.A. Storms, North American Aviation, Inc. **"Optimization and Off-Optimum Operation of Space Peltier Refrigeration Systems"**, By M.E. Stelzriede, North American Aviation, Inc. **"The Role of Environment in Land Locomotion"**, By Capt. R.A. Liston, Ordnance Tank Automotive Command. **"Mobility of Missile Launch Equipment in the Arctic"**, By F.C. Bunn, Army Rocket & Guided Missile Agency. **"Mobility as an Environmental Tool (Use of Shrouds)"**, By F.P. Merry, White Sands Missile Range. **"Shock Testing with Electrodynamic Shakers"**, By H.O. Lewis, Lockheed Aircraft Corporation. **"A Study of Repeatability Obtainable in Shock Testing"**, By W.J. Sieger and E.H. Copeland, Sandia Corporation. **"Unique Problems Associated with Environmental Testing of Acceleration – Time Sensing Devices"**, By N.R. Anderson, Sandia Corporation. **"Evaluation of Precision Centrifuge or Guidance Accelerometers"**, By R. Uradnicek, AC Spark Plug Division. **"No Loss Storage of Liquid Hydrogen in Space"**, By D.L. Williams & I. Catton, Douglas Aircraft Company, Inc. **"Regeneration of Breathing Oxygen from Exhaled CO-2"**, By J.F. Foster & J.S. McNutly Battelle Memorial Institute. **"Analysis of Atmospheric Regeneration and Control Problems for Aerospace Vehicles"**, By W.B. Fox or E.B. Thompson, Jr., Wright Air Development Division. **"The Cryogenic Pumping of Non-Condensible Gages"** By O.O. Haroldsen and A. Cohen, Convair (Astronautics) Division. **"Organizing the Field of Environmental Engineering"** By Dr. William B. Brierly, Quartermaster Research and Engineering Command. **"A Realistic Engineering Approach to Environmental Testing"**, By B. Lavitol, Ticatinny Arsenal, LRAWL. **"Simplified Approaches to Environment Simulation"**, By E.M. Szymanski, International Business Machines, Inc. **"Trends in Environmental Testing"**, By R.M. Daniel, Northrop Aviation. **"The Effects of Filter Bandwidth in Spectrum Analysis of Random Vibration"**, By W. Forlifer, Aircrafts Armanents. **"A Simplified Approach to the Amplitude Distribution Analyzer for Random Vibration"**, By C.W. Diem, Chrysler Corporation Missile Div. **"Environment and Its Effect on Man-Machine Design"**, By M.A. Larue, The Martin Company. **"The Effect of Ions on Human Behavior"**, By R.A. Duffee & H.G. Schutz, Battelle Memorial Institute. **"Problems in Determining Space Environmental Design Criteria"**, By A.D. Goedeke, Douglas Aircraft Company, Inc. **"Wind Tunnel Studies with Scale Model Simulated Snow"**, By Dr. Robert Gerdel, U.S. Army Snow, Ice & Permafrost Establishment. **"Simulation of the Rain Environment"**, By M.H. Simpson, Pitman-Dunn Laboratories. **"Water Entry Testing Using Rocket Sleds"**, By D.W. Bauder, Sandia Corporation. **"A Unique Acoustic Chamber for High Energy, Progressive Wave Testing"**, By J.B. Overton, U.S. Naval Missile Center. **"Acoustics in Manned Space Vehicles"**, By W.F. Rector, Convair (Astronautics) Division. **"The Simulation of Re-Entry Conditions in the Wind Tunnel"**, By Dr. K.R. Enkenhus, U.S. Naval Ordnance Laboratory. **"Facility for Simulating Missile Guidance Compartment High Altitude and Temperature Environment"**, By J.D. Losse, AC Spark Plug Division. **"Vacuum and Space Environments"**, By W.E. Scott, Grumman Aircraft Engineering Corp. **"Boeing High Temperature – Altitude Simulation Facilities"**, By J.D. Stuart, Boeing Airplane Company. **"Operation of a Solar Space Environmental Simulator"**, By H. Mark, National Aeronautics and Space Administration. **"Criteria for Design of Military Equipment for Reliable Performance During Environmental Simulation"**, By T.W. Johnson, Jr., U.S. Naval Bureau of Weapons. **"Environmental Specifications and Their Application"**, By M.P. Ornstien, Wright Air Development Center. **"Planning, Organizing and Administering an Environmental Test Program"**, By A. Koch, Ticatinny Arsenal, LRAWL. **"Interactions in Combined Environments"**, By J.S. Arnold, Stanford Research Institute. **"A Vibration Amplitude Recording System for Design Evaluation Studies"**, By Irving and Milne, Johns Hopkins University. **"Reliability of Piezoelectric Accelerometers for Shock Measurement"**, By E.I. Feder & E.J. Straus, Gulton Industries, Inc. **"In-Flight Sound Level & Vibration Conditions in Naval Air Electronic Equipment Compartments"**, By J. Nelson Tait, Naval Air Development Center. **"Optical Phenomena of Interplanetary Matter"**, By Dr. W.O. McMinn, American Machine & Foundry Company. **"A Review of Extra-terrestrial Matter"**, By D.E. Winer, American Machine & Foundry Company. **"Possible Hazards from Comets, Cometoids and Meteor Streams"**, By D.H. Robey, Convair (Astronautics) Division. **"Controlled Temperature Requirements for Environmental Testing of Component Parts"**, By R.H. Paccone, International Business Machines Corporation. **"Corrosion Problems Encountered in Silo Storage of Missiles"**, By L.E. Gatzek, Space Technology Laboratories. **"Effects of Environment on Mechanical Properties of Metals"**, By H.E. McCoy, Oak Ridge National Laboratories. **"Transient Radiation Effects on Guided Missile Systems"**, By Glen Elder, White Sands Missile Range. **"The Sea as an Environmental System Tests Under Simulated Conditions (Project Mercury)"**, By L. Richardson and Maloney, McDonnell Aircraft. **"Noise and Vibration of Personnel in Aero-Space Systems, and the Shipboard Vibration Environment"**, By E. Buchmann, David Taylor Model Basin. **"Shipboard Shock Environment"**, By H.L. Rich and R.E. Baker, David Taylor Model Basin. **"Human Protection in Abrupt Acceleration Environments"**, By Charles A. Dempsey, Wright Air Development Division. **"Life Support Simulation of the Environment in Aero-Space Medical Research"**, By Von Gierke, Cole and Grob, Wright Air Development Division. **"Instrumentation for Monitoring the Space Environment"**, By B. Wacholder, Radio Corp. of America. **"Outer Space Environment Simulation"**, By P. Marfone and D. Grady, General Electric Co., MSVD. **"Design Solution for Space Simulation"**, By Hohn Galhard, General Electric Co., MSVD. **"High Vacuum Orbital Simulator"**, By W.G. Camack and C.A. Ellis, Jr., Lockheed Aircraft Corp. **"Future Space Chamber Needs"**, By A.H. Abernathy, Holloman Air Force Base. **"Environmental Measurements in Probe Type Sounding Rockets"**, By C.E. Roth, Jr., Aerojet-General Corporation. **"Some Structural Load Measurement Problems on Advanced Flight Vehicles"**, By W.H. Michie, Wright Research & Development Command.

SEE YOU THERE?

MODERN PUBLISHES CATALOG OF FREE TECHNICAL FILMS

Modern Talking Picture Service has published a new guide to technical films for use by business, industry, and commercial and engineering colleges. More than 130 films dealing with specific technical subjects are offered on free loan for the asking in the catalog.

Titled "Modern's Catalog of Free Loan Technical Films," the listing includes topics in the realm of the pure sciences as well as those affecting practical considerations of production and distribution. Almost all basic American industries are represented by one or more films described in the catalog.

The films are being offered free to adult groups connected with business or industry, or to study groups in business or engineering colleges. All are 16mm-sound sound films, from a quarter-hour to a half-hour in length. Most are in color. Major corporations in various industries, as well as trade associations representing industrial and commercial groups, are sponsoring distribution of the films.

All films listed in the catalog will be available from Modern Talking Picture Service via 30 regional film libraries throughout the country. Copies of the catalog may be obtained without charge by writing to Modern at 3 East 54th Street, New York 22, N.Y., or any Modern film library.

ATOMIC ENERGY OF CANADA LIMITED PUBLISHES HANDBOOK

Two new Publications are being offered by the A.E.C.L., The first is a new General Products Catalog "D".

The second is the Atomic Energy of Canada Limited Radioisotope Handbook RP–3. It contains a variety of useful general and technical information. There is no charge for quantities up to ten. Larger quantities are available at cost price, thirty cents. Copies may be obtained by writing on company letterhead requesting copies of the Catalog "D" or Radioisotope Handbook to: Atomic Energy of Canada Limited, Commercial Products Division, P.O. Box 93, Ottawa, Canada.

For our readers information we are publishing the following complete index of technical articles which have appeared in the Institute's Official Publications since the first issue appeared in October 1958.

OCTOBER 1958
1. *Vibration Testing* by F.P. Klein

DECEMBER 1958
1. *Acoustic Vibration Testing* by Jack Fromkin
2. *Power Amplifiers and System Equalization* by James A. Ross.
3. *How To Get What You Want* by William L. Vandal.
4. *The Meaning of Natural Frequency* by G.E. White.

FEBRUARY 1959
1. *Techniques For Design to Shock and Vibration Conditions* by Charles T. Morrow.
2. *The Immersion Test Set* by Vernon Bradfield

APRIL 1959
1. *Acoustical Environmental Testing* by B.R. Vernier
2. *Final Report on a Facility for Horizontal Vibration with Electromagnetic Exciters* by F.P. Klein.

JUNE 1959
1. *Keep Them Breathing*
2. *Accelerometer Calibration* by Alvin B. Kaufman.
3. *Engineers Can Write Better Technical Reports* by John Kent.

AUGUST 1959
1. *Improved Optical System, Part I* by L.E. Hayes.
2. *Criterion For Chamber Specification* by William P. Cool.

OCTOBER 1959
1. *Sound-Induced Vibration* by Preston W. Smith Jr. and Miguel C. Junger.
2. *Improved Optical System, Part II* by L.E. Hayes.

DECEMBER 1959
1. *Transient High Temperature Simulation* by R.H. Canning and Tang Yee.
2. *Low and High Temperature Chambers* by Stuart Giles.
3. *Random Output of a Complex Motion System with Random Input* by H. Beckwith

FEBRUARY 1960
1. *Management of an Environmental Laboratory* by C. Brown.
2. *Large Fixture Unequalized Response* by J.I. Bacile and W.J. Reich.

APRIL 1960
1. *A System For Direct Readout of Vibration Transmissibility* by F.A. Kramer.
2. *Operation of Vacuum Equipment in Connection with Altitude* by Paul H. Brandt.
3. *Back-to-Back Calibration of Accelerometers* by William F. Cox.

JUNE 1960
1. *A Synopsis of Natural Environments to Heights of 1000 KM, Part I* by A.P. Harris and E.W. Parrott.
2. *Development of a Combined Climatic, Static, and Dynamic Environmental Test Facility* by J.J. Hendrix, E.H. Moore and K.M. Murphy.
3. *Biological Effects of High Intensity Noise Part I* by William P. Bagley

AUGUST 1960
1. *A Synopsis of Natural Environments to Heights of 1000 KM, Part II* by A.P. Harris and E.W. Parrott.
2. *Vacuum Tank for Container Testing* by D. Stern.
3. *Biological Effects of High Intensity Noise, Part II* by William P. Bagley.

OCTOBER 1960
1. *Dynamic Amplification of a Two-Degree-of-Freedom System* by Josef S. Pistner and Herbert Reismann.
2. *Reliability Planning in Space Systems, Part I,* by Vernon L. Grose.
3. *Design for Manned Reentry Glide, Part I,* by Raymond J. Comenzo and Lawrence D. Wing.

DECEMBER 1960
1. *Reliability Planning in Space Systems, Part II,* by Vernon L. Grose.
2. *Design for Manned Reentry Glide, Part II,* by Raymond J. Comenzo and Lawrence D. Wing.

I.E.S. NEWS LETTER

LOS ANGELES CHAPTER

Ray Silvers, Advanced Systems, Federal Systems Division, IBM Corporation, spoke to members and guests of the Los Angeles Chapter, Institute of Environmental Sciences, Monday, January 23, at 7:30 P.M. in the Auditorium, 5th Floor, IBM Building, 3424 Wilshire Boulevard, Los Angeles.

He discussed advanced system areas of space, command and control for new computers, specifically concerning environmental conditions under which they have to be designed.

Following Mr. Silver's talk, a tour of the IBM Data Center was arranged.

Robert Shaidnagle, Chapter President, Ling Electronics Division, Ling Electronics, Inc., Anaheim, Calif., presided. Ray Tomren, Western Gear Corp., Lynwood, Calif. Was program chairman.

David A. Lee and Gordon Reiter of the technical staff of Space Technology Laboratories, Los Angeles, discussed biological and psychological aspects of "Zero G" conditions in the environmental testing of missiles at a dinner meeting of the Los Angeles Chapter, Institute of Environmental Sciences, held Monday, February 6, at Rand's Roundup, 83rd and Figueroa Streets, Los Angeles.

Robert Shaidnagle, Chapter President, Ling Electronics Division, Ling Electronics, Inc., Anaheim, Calif., presided. Ray Tomren, Western Gear Corp., Lynwood, Calif., was program chairman.

NORTHERN CALIFORNIA CHAPTER

TIME: 7:30 Meeting

LOCATION: Moores Prime Rib Cart
210 El Camino Real
Belmont, California
(South of Belmont Theater)

SPECIAL EVENT: Presentation of Fellowship Award

PROGRAM: Subject: Visual Aids in Vibration Analysis
Environmental Testing Using High-Techniques by Dr. L. Curt Foster, Zenith Radio Research Corp., Menlo Park, Calif.

Northern California Chapter Officers, Institute of Environmental Sciences. Left to right front row, Don E. Richardson, Robert C. Geiger, John D. Campbell. Back row, Harry F. Cuzner, Ron E. Lewis, Ray G. Danehy and Ben Ventresca (not shown).

Left to right, Harry F. Cuzner, Robert C. Geiger, John D. Campbell.

Use of Slip Sync Systems to Study Mechanical Resonance, by Mr. William Cox of Chadwick-Helmuth Co., Monrovia, Calif.

The Use of Optron Model 710 in a Vibration Laboratory by Mr. Norman Chapman of Moxon Electronics Corp., San Mateo, Calif.

TECHNICAL MEETING CHAIRMAN: Mr. Alex B. Millar

NEW YORK METROPOLITAN CHAPTER

A meeting was held an January 19, 1961 at Busto's Restaurant. Guest speaker for the evening was Mr. M.C. Kramer, Technical Sales Manager, Pure Carbonic Company. His topic of discussion was "Carbon Dioxide Refrigeration". The film, "The Carbon Dioxide Story" was shown.

Tentative Program Schedule

February Meeting

THURSDAY, FEBRUARY 16, 1961, Busto's Restaurant, 11 Stone Street, New York City, Dinner at 6:30 P.M. Meeting at 8:00 P.M., MECHANICAL IMPEDANCE TESTING, Mr. Wilson Bradley, Jr., Endevco Corporation

May Meeting

THURSDAY, MAY 18, 1961, Brooklyn Navy Yard, TOUR OF ENVIRONMENTAL FACILITIES

GREATER CHICAGO AREA CHAPTER

If you haven't been at the past meetings, you have been missing out. Attendance has been excellent. An average of 50 to 60 per meeting. However, you still have a chance to cash in on those meetings coming up. Here is a rundown of what's in store.

January 11, 1961-Dr. Earl Foster of Collins Radio Co., Cedar Rapids, Iowa. The subject of Dr. Foster's talk will be on a research program to determine a possible correlation between random and sinusoidal excitation. This study differs from that usually reported damage rather than fatigue type failures.

February 8, 1961-Mr. James Hill, North American Aviation, Columbus, Ohio. Mr. Hill will discuss acoustic testing. He will show the need for qualifying component parts and typical structures to acoustic environments and the various methods of failure, both permanent and temporary. Difficulties in the simulation of acoustic environments assumptions made in theories of failure mechanisms and current approaches to the acoustic reliability program are mentioned.

March 8, 1961-Mr. Charles Theodore of Ling Electronics, Anaheim, California, will discuss sinusoidal vibration. A tour of the Sundstrand Aviation Div., Rockford, Illinois, will be included.

April 12, 1961-Mr. David Earls, Wright Air Development Div., Dayton, Ohio. Mr. Earls will speak on shock testing. Mr. Earls has evaluated many of the newer machines and speaks with authority. Plant tour of Admiral Corp. test facilities includes a demonstration of one of the newer shock machines. Another high point of this meeting is FREE-delicious refreshments courtesy of of Admiral Corp.

Continued on page 25

Continued from page 12

oscillation. A section of the first cycle's acceleration vs. time response of this method approximated the test requirement. The disadvantage of this method is that the vertical mounted component shock tester imparts a 1 g deceleration force to the switch prior to the start of the test cycle. This force would actuate the switch so some device would be required to hold the switch closed until the test cycle had begun.

The second method uses a compound pendulum mounted on the large centrifuge. When the pendulum is released it is free to swing through an arc of 180 degrees. At the end of the swing it is latched in its final position. With this system the G switch is mounted on the pendulum arm with its sensitive axis parallel to the centrifuge acceleration axis. The centrifuge speed is adjusted to give the 5 g acceleration required. When the latch is released electrically the pendulum swings through 180 degrees and is latched in its final position.

During the 180 degree swing the G switch experiences an acceleration reversal from 5 g's in one direction to 5 g's in the opposite direction. The acceleration vs. time characteristic is elliptic (close to half a cosine wave), but during the zero acceleration region which is most important the reversal rate is almost linear. The system has many advantages. First, it performs the test as specified. That's enough, generally, but it does more than that -- it makes it easy to vary the parameters of the test. The starting G level is easily adjusted. The reversal rate is easily changed by adding weight to the pendulum to change its polar moment of inertia. This adjustment is made by measuring the period of the pendulum swing. Naturally, the period is different in a one g gravitational field and an "X" g acceleration field on the centrifuge, but the difference effect is easily calculated. There are a few effects which should be considered. All the component axes are being subjected to the acceleration reversal. At the time the acceleration is zero in the sensitive axis of the G switch the acceleration is maximum in a perpendicular axis. In our case this didn't bother us as the moving element of the switch was constrained to move along a line and the frictional effects were not considered to be harmful. This had previously been borne out by the tests performed on the component impactor. This may not be true in some applications. The effect of the variation of the centrifuge radius arm was less than 5% and was ignored. The Coriolis acceleration was neglected also. During the tests the actual acceleration was recorded with Statham accelerometers, so these effects are included in the response curve. They do not contribute enough to be noticeable. It is a neat system and we're proud of it.

I intended to discuss combined vibration and sustained acceleration testing next, but before we get into that we should look at our hydraulic shakers. The Environmental Test Lab is fairly well equipped with electrodynamic shakers as we have 12,500; 5,000; and 1,500-pound force systems. The electrodynamic shaker performance falls off in the low frequencies and below 20 cps it is not worth talking about. To overcome this deficiency in our shake equipment we did some experimenting with missile parts -- servo amplifier, servo valve, wing actuator, and feedback potentiometer. The results of these experiments were so encouraging that we designed a 10,000-pound force system using the missile parts with a commercial double-ended hydraulic cylinder. The system has dual shakers and worked fine during a recent TALOS Weapon Container Test series where specimens up to 8,000 pounds total weight were tested between 2 and 300 cps. The output above 50 cps is always open to question. We are satisfied with its performance below 50 cps and will take what we get above 50 cps. There is one basic problem in a hydraulic shaker design. That is -- velocity limiting in the system. Large force outputs with big displacements require high flow rates through the hydraulic supply, servo valve, and cylinder. The missile servo valve was completely inadequate for a high force system, so we bought two 45 gpm Sanders Associates Valves. This eliminated the velocity limiting in the servo valve, but now we have a velocity limit in the hydraulic supply. The most expensive part of a hydraulic shaker system is the hydraulic supply. If the hydraulic supply is available, the servo amplifier, servo valve, hydraulic cylinder, and mechanical parts are relatively inexpensive. A plan is now underway to utilize the 60 gpm, 5000 psi hydraulic power supply which drives the E.T.L.'s large centrifuge to provide the large flow rates required for hydraulic shaker use. The electronic portion of the system has evolved also. The Sanders Associates valve had different coil characteristics than the missile servo valve, so a new servo amplifier was designed. One of our electronic engineers was assigned to the problem and before we knew it he had a complicated servo amplifier built which worked wonderfully, but took an electronic genius to understand. An effort was made to reduce the complexity of this servo amplifier with the end result being a new one-tube servo amplifier which performs as well as the other amplifier. At the present time, we are mulling over piston centering and protective circuitry for the hydraulic shaker system.

The hydraulic shaker system is perfect for combined vibration and sustainer acceleration testing on a centrifuge if the vibration can be limited to the low frequencies. There is no critical problem with a hydraulic shaker in a high acceleration environment as the hydraulic cylinder is a rugged piece of equipment and will withstand the large forces without extra support.

I do hope that my article will assist some environmental engineers in the solution of their problems; amuse other environmental engineers as they recognize a similarity of problems in their own experiences; and, finally, to encourage environmental engineers to prepare articles giving their own experiences.

Reference 1-Pneumatic-Hydraulic Impactors for Producing Controlled Accelerations S.P. Sanders-23rd Bulletin of Symposium of Shock and Vibration.

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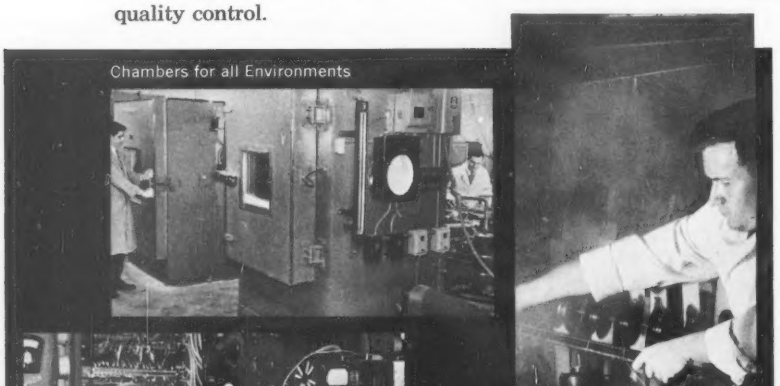

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The Journal always welcomes comments on any article published in the Journal. Mr. J.T. Muller of J.T. Muller Dynamic Testing, Inc., Hanover, New Jersey has sent us another interesting approach to the article entitled: *Dynamic Amplification of a Two Degree of Freedom System*, published in the October 1960 issue.

EDITOR

"There is another approach to this problem which will substantiate the usual derivation of an amplification factor <2. From equation 5 they obtain the amplification factor A

$$A = 1 + \frac{\omega_1^2 \cos \omega_2 t - \omega_2^2 \cos \omega_1 t}{\omega_2^2 - \omega_1^2}$$

or the equivalent

$$A = \frac{\omega_2^2 (1 - \cos \omega_1 t) - \omega_1^2 (1 - \cos \omega_2 t)}{\omega_2^2 - \omega_1^2}$$

from which we see immediately that

$$A_{max} = \frac{2\omega_2^2}{\omega_2^2 - \omega_1^2}$$

Without getting involved in frequency ratios and the authors' unusual choice of making the first mode the higher one, this leads to

$$A_{max} = 1 + \sqrt{\frac{k_2 + k_1}{k_2}}$$

and is shown in Fig. 2 which exhibits amplification factor >2.

The result depends on the concept of static deflection. The authors have selected the static deflection at a point within the system.

It is perhaps more realistic to consider the overall or external deflection of the system. In case (a) for instance, the static deflection would be at the point where the force is applied or

$$\frac{F}{k_1} + \frac{F}{k_2} = \frac{F}{k_1}\left(\frac{k_2 + k_1}{k_2}\right)$$

The amplication factor is now

$$A = \frac{k_2}{k_2 + k_1}\left[1 + \sqrt{\frac{k_2 + k_1}{k_2}}\right]$$

and this has an upper limit of 2 again.

Continued from page 22

May 10, 1961-Brig. Gen. Don Flickinger, Air Research & Development Command, U. S. Air Force, Andrews Air Force Base, Washington, D. C. General Flickinger will tell us about the human factors involved in space. He is the assistant for bio-astronautics. Much of his talk will include the Mercury Project, as he works closely as an advisor in this NASA program. This is a meeting that you won't want to miss.

SAN DIEGO CHAPTER

The January meeting on Jan. 11, was a field trip to Convair Astronautics rather than the usual dinner meeting.

The field trip began with briefings on the Atlas ICBM program and on present and future space programs. A conducted tour was taken through the Environmental Test Laboratories. Some of the highlights of the tour were:

1. A 20-foot radius, 220,000 g-lb. centrifuge.
2. A 14,000 lb. rms force random vibration system.
3. A high altitude testing chamber capable of producing vacuum down to 3×10^{-7} mm Hg.
4. Several 2,500 and 5,000 lb. rms force random vibration systems used for combined temperature-vibration and temperature-altitude-vibration testing. One of these systems was demonstrated with a tape recorded program consisting of voice and music reproduction, sinusoidal frequency sweeps, and random noise vibration. (Hi-fi addicts usually flip when they hear this one.)

The field trip concluded with a bus tour through other areas of the Astronautics plant.

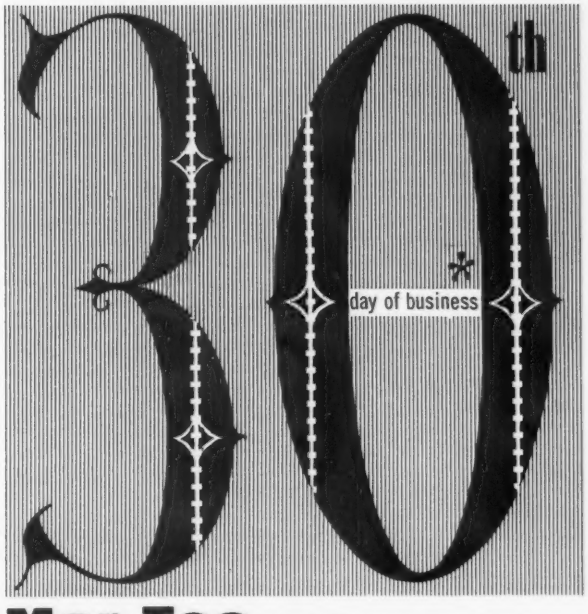
Continued from page 9

The catenoidal horn-test chamber panels are made from plywood three-quarters of an inch thick. The reason for making this combination from plywood was for simplicity and low cost. It is suspected that in the higher frequencies, the desired increase in sound pressure level is not obtained while traversing the length of the horn as had been designed, partially because of the damping characteristics of the side wall materials in the catenoidal horn and test section. A modification or improvement to this horn and test section might be in order. A coating on the horn and test section could be applied using marble or a concrete liner of some sort to considerably decrease the absorbtion qualities of the present plywood.

It is strongly recommended that a single amplifier be used in future installations to supply power to the acoustic drivers. Output impedance matching, phasing, and balancing of output energy are needless problem areas opened when using multiple power sources.

REFERENCES

(1) Vibration and Sound, by P.M. Morse, Second Edition, Published by McGraw-Hill, Pages 282 - 285.



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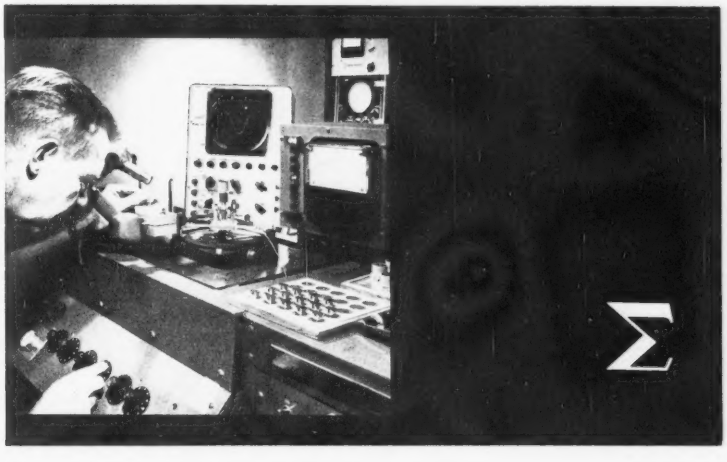

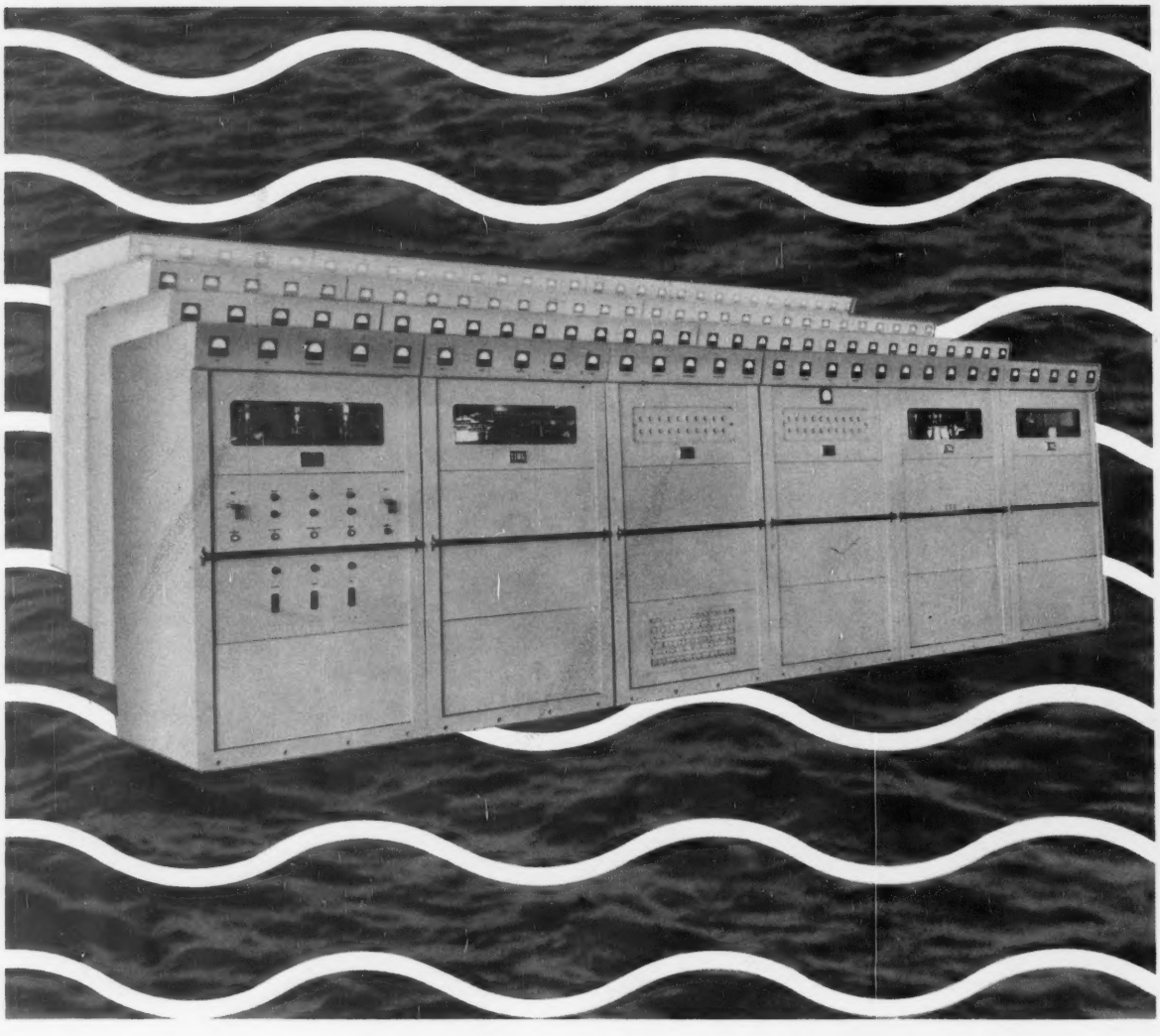

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